Chapter

Herbs and Spices—New Processing Technologies. *Syzygium aromaticum*: Medicinal Properties and Phytochemical Screening

Vikrant Kumar, Deepak Mishra, Mukesh Chandra Joshi, Priyanka Mishra and Megha Tanwar

Abstract

All over the world, Plants have found to be a valuable source of herbs and spices for a long period of time to maintain the human health. Varieties of herbs and spices have been used to impart an aroma and taste to food for last few centuries. Several applications of plants species have been reported as antioxidative, anti-inflammatory, antidiabetic, antihypertensive and antimicrobial activities. Currently efforts are focused on their scientific merits, to provide science-based evidence for their traditional uses and to develop either functional foods or nutraceutical behavior. India is well recognized all over the world for their variety of herbs, spices and medicinal biodiversity. The WHO has listed more than 21000 plants, which are used for their medicinal purposes either in the form of essential oil or in the form of flavor. Among these, more than 2500 species and herbs are found in India, however; among them more than 150 species are used commercially on large scale. In India, the use of spices and herbs in the form of essential oil or in the form of flavor are traditionally used in routine treatment. For example, Curcumin which is found in turmeric are frequently used in medical facilities to wound healing, rheumatic disorders, and gastrointestinal symptoms etc.

Keywords: *Syzygium aromaticum*, essential oil, Flavonoids, Eugenol, phytochemistry

1. Introduction

Herbs and Spices are seeds, fruits, roots, bark, berries, buds, or vegetable substances, which have been used from decades primarily for flavoring, coloring, or preserving food and formulation of medicinal items. Globally, India and Pakistan, have been notable for their tremendous production of spices and flavors. It is worldwide accepted that a wide range of physiological and pharmaceutical benefits can be derived from spices. Numerous health problems, like neurodegenerative diseases and oxidative stress, are controlled and restored with plant based eating regimens, because they contain various valuable chemical compounds and antioxidants [1]. Various metabolic diseases and age-related issues are associated with oxidative mechanisms in the human body are also cured by the proper use of herbs. Due to nonhazardous impact of flavors on people, they are viewed as safe for use in food with no adverse effect. Major spices and herbs are harvested and used in the subcontinent, viz. black pepper (*Piper nigrum*), cloves (*Syzygium aromaticum)*, cinnamon (*Cinnamomum verum*), seeds of flax (*Linum usitatissimum*), cardamom (*Elettaria cardamomum*), poppy (*Papaver somniferum*), fenugreek (*Trigonella foenum-graecum*), cumin (*Cuminum cyminum*), sesame, fennel, carom, ajwain, coriander, turmeric, tamarind, ginger, onion, garlic, and red chilies. These spices are secret fortune of various therapeutic components which help directly and indirectly for various health disorders. In this chapter we are focusing Clove (*Syzygium aromaticum*), which has been employed for centuries as food preservative and various medicinal purposes including its antimicrobial and antioxidant properties. The health benefits associated with the consumption of *Syzygium aromaticum* are briefly discussed below and shown in **Figure 1**.

Syzygium aromaticum is a tree which belongs to the family Myrtaceae and originate from Indonesia and is one of most valuable and second most important spice in the world trade. Various synonyms are used for the Clove, viz. *Caryophyllus aromaticus, Caryophyllus silvestris, Eugenia caryophyllus, Jambosa caryophyllus* and *Myrtus caryophyllus* [2]. The tree of *Syzygium aromaticum* attains medium size and reaches up to 20 m in height. Depending on the variety of this tree its canopy shape varies from cylindrical to pyramidal [3]. The life span period of this tree for up to 100 years and above. The tree prefers to grow in very much depleted soil with adequate soil moisture. The tree requires high atmospheric temperature in the range of 25 to 35°C with heavy sunlight, besides this well-distributed rainfall and high humidity i.e. >70% is also necessary condition for their growth [4]. In India cloves tree are harvested in deep black loamy soil of humid tropics and successfully grows in the red soils of midlands of Kerala and in the hilly territory of Western Ghats in Karnataka and Tamil Nadu [5].

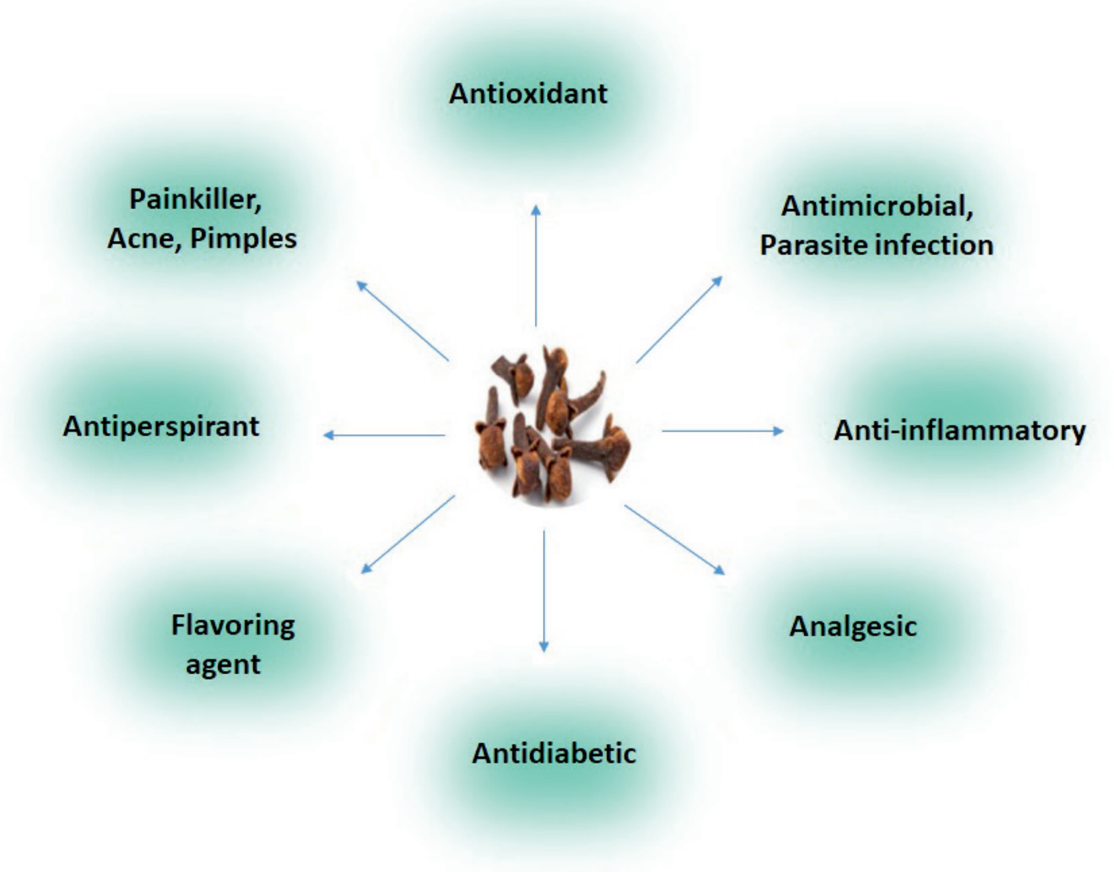

Figure 1.
Uses of S. aromaticum.

The aromatic flower buds which has characteristic odors of this plant are known as cloves and are commonly used as a spice and several therapeutic areas to treat variety of disease and infections like nausea, vomiting, cough, diarrhea, dyspepsia, flatulence, stomach distension, and gastrointestinal spasm; relieve pain; cause uterine contractions; and stimulate the nerves [6]. Because of these it makes an attraction for commercially cultivation of cloves in different part of the world like India, Pakistan, Sri Lanka, as well as in African countries. India becomes second largest consumer of clove after the Indonesia [7]. The plant is also used as a folk medicine in diuretic, odontalgic, stomachic, tonicardiac, and condiment with carminative and stimulant effects [8]. The essential oil derived from this aromatic plant not only serves as a fragrance and flavor agent, but also used as a dietary antioxidant to prevent several diseases caused by a free radical [9, 10]. Clove are rich in flavonoids, organic acids, volatile acids phenolic components like eugenol, terpenoids, tannins, and gallic acid, which have great potential for pharmaceutical, food, and agricultural applications [11]. In Brazil and other tropical countries, faces a serious health problem cause by Dengue, is countered by clove, due to its larvicidal activity [12].

1.1 Morphology of *Syzygium aromaticum*

The clove is aromatic spice tree mainly contains leaves and buds which are the common commercial part of the tree. The term clove is taken from French word 'Clove' and 'Clou' which signifies 'Nail'. Clove is conical myrtle, medium sized tree with straight trunk which grows up to 18 to 20 m in height. The branches of clove tree are grayish, thick and semi erect. Leaves are enormous elongated to elliptic, simple obovate opposite, glabrous and possess lots of essential oil glands on the lower surface. Tree started flowering bud formation in around 7 years and keeps flowering for a very long time or more after plantation. Flowers are small, crimson in color and are bisexual borne at the terminal ends of the small branches. Each peduncle carries 3 to 4 stalked flowers and inflorescence length remains between 4 to 5 cm. Initially, the color of the flower buds is pale yellow with glossy appearance and turn green to bright red on maturing. These are reaped when they become dark red ellipsoid berry [12, 13].

1.2 Chemical constituents of clove

Pharmacologically, Clove is found to be rich in pharmacophore phenolic compounds like flavonoids (quercetin), hydroxybenzoic acids, hydroxyphenylpropens, hydroxycinamic acids, eugenol and derivatives of gallic acid. [11–14]. It has also been found that 18–20% of essential oil are present in the stem, buds and leaf of clove flower with different chemical compostions having variety of applications [15, 16]. These oils are colorless or pale yellow with a particular flavor and taste [15, 16].

Alma, *et al.* in 2007 [17] extracted and reported the presence of essential oil from bud of Clove which is yellow in color and have high density than water. They extracted and characterized the components as eugenol (87%), chavibetol (19.7%), β-caryophyllene (13%), eugenol acetate (8.01%), trisiloxane-1,1,1,5,5,5-hexa-methyl-3,3-bis-[(trimethylsilyl) oxy] (1.7%), etc. [18, 19], Marya, *et al.* 2012 [20] and Kasai, *et al.* 2016 [21] further studied and reported the presence of eugenol (74.32%), β-caryophyllene (15.94%) and eugenol acetate (5.8%) as major component in a Clove bud. Another component methyl-n-amyl ketone which has characteristic fruity and fresh odor was also found in buds of clove (2001) [22]. Xu, *et al.* (2016) [23] studied the chemical composition of Clove bud essential oil by performing Gas Chromatography-Mass Spectrophometery (GC–MS) and reported the presence of caryophyllene oxide, α-selinene, cadinene, 2-pinene etc. with the previously reported oil. Fankem *et al* [24] confirmed the presence of oxygenated monoterpenes (89.06%), monoterpenes (0.04%), sesquiterpenes (10.6%) and linear components (0.03%) in Clove bud essential oil along with eugenol.

Essential oil also extracted from leaf of Clove and known as Clove leaf essential oil. The oil which is extracted from leaf have pleasant odor and faint yellow in color. Jirovetz, *et al.* and coworkers in 2006 [25] reported the presence of 23 other compounds along with α-humulene, eugenol and their acetate derivatives as major components. These finding suggested that eugenol, chavibetal, β-caryophyllene, eugenol acetate are the major components in the tree of Clove. These essential oils are also found in the stem of Clove [26–28].

Bao, *et al.*, 2012 [29], reported several other phenolics components from methenol extract of *S. aromaticum*, viz. biflorin, kaempferol, rhamnocitrin, myricetin, gallic acid, and ellagic acid (**Figure 2**). Bao, *et al.*, 2012 [29], also reported the presence of eighteen hydrolyzable tannins from an aqueous acetone extract of dried flower buds of *S. aromaticum* such as aromatinin A, platycaryanin A, bicornin, syzyginin A, alunusnin A, rugosin C, tellimagrandin II, casuarictin, heterophylliin D, rugosin D, rugosin F, euprostin A, 1,2-di-Ogalloyl-3-*O*-digalloyl-4,6-*O*-(*S*)-hexahydroxydiphenoy-β-D-glucose, alienanin B, squarrosanin A, casuarinin, syzyginin B, 1,2,3-tri-*O*-galloyl-β-D-glucose, and 1,2,3,6-tetra-*O*-galloyl-β-D-glucose.

1.3 Pharmacological activities of clove oil

The essential oil or chemical compounds which were extracted from different parts clove exhibit variety of pharmacological activities and several literatures have been reported in which they exhibit anticancerous, antimicrobial, antidiabetic, anti-inflammatory, antidepressant, antiulcer, antioxidant, antinoceptive, and antiprotozoal, etc. (**Figure 3**).

1.4 Antimicrobial activity

The oil isolated from Clove, has wide range of medicinal application. It is essentially used in the manufacturing of variety of Indian Ayurvedic and Chinese medicine. These oils are also used in the manufacturing of antibiotics because its antimicrobial properties. Numerous reports exhibit that its component eugenol inhibiting bacterial migration, bacterial adhesion, fimbriae formation of *Gram*-negative bacteria such as *Escherichia coli*, *Salmonella*, *Pseudomonas aeruginosa*, etc., and *Gram*-positive bacteria such as *Staphylococcus*, *Streptococcus*, *Listeria*, etc. [30].

Matan *et al.* (2012) [31] reported that Clove oil exhibit strong antimicrobial activity against *Penicillium* sp., *Aspergillus flavus* and *Staphylococcus aureus* found on dried fish (*Decapterus maruadsi*). Zengin & Baysal (2014) [32] were found that they exhibit activity against three *Gram*-positive bacteria such as *Listeria innocua, Carnobacterium divergens* and *Staphyloccous aureus* and also inhibit potential activity against four *Gram*-negative bacteria like *Salmonella typhimurium, Escherichia coli, Serratia liquefaciens* and *Shewanella putrefacians*. The data strongly proved that Clove essential oil inhibit the growth of all bacteria whether it is *Gram*- positive or *Gram*-negative, while the main constituent of the essential oil was found to be inactive towards *Shewanella* and *Listeria* [33]. Abdulwahab Kammon, *et al.* in 2020 reported antimicrobial activity of Clove oil against *Gram*-negative bacteria isolated from chickens *E. coli (1 avian pathogenic E. coli (APEC) and 2 non-pathogenic E. coli), Salmonella enteritidis, and Salmonella spp.,* which were isolated from chicken at the Department of Poultry and Fish diseases [34]. In the food industry clove essential oil have received a prime attention because of *L. monocytogenes* contamination, especially for food

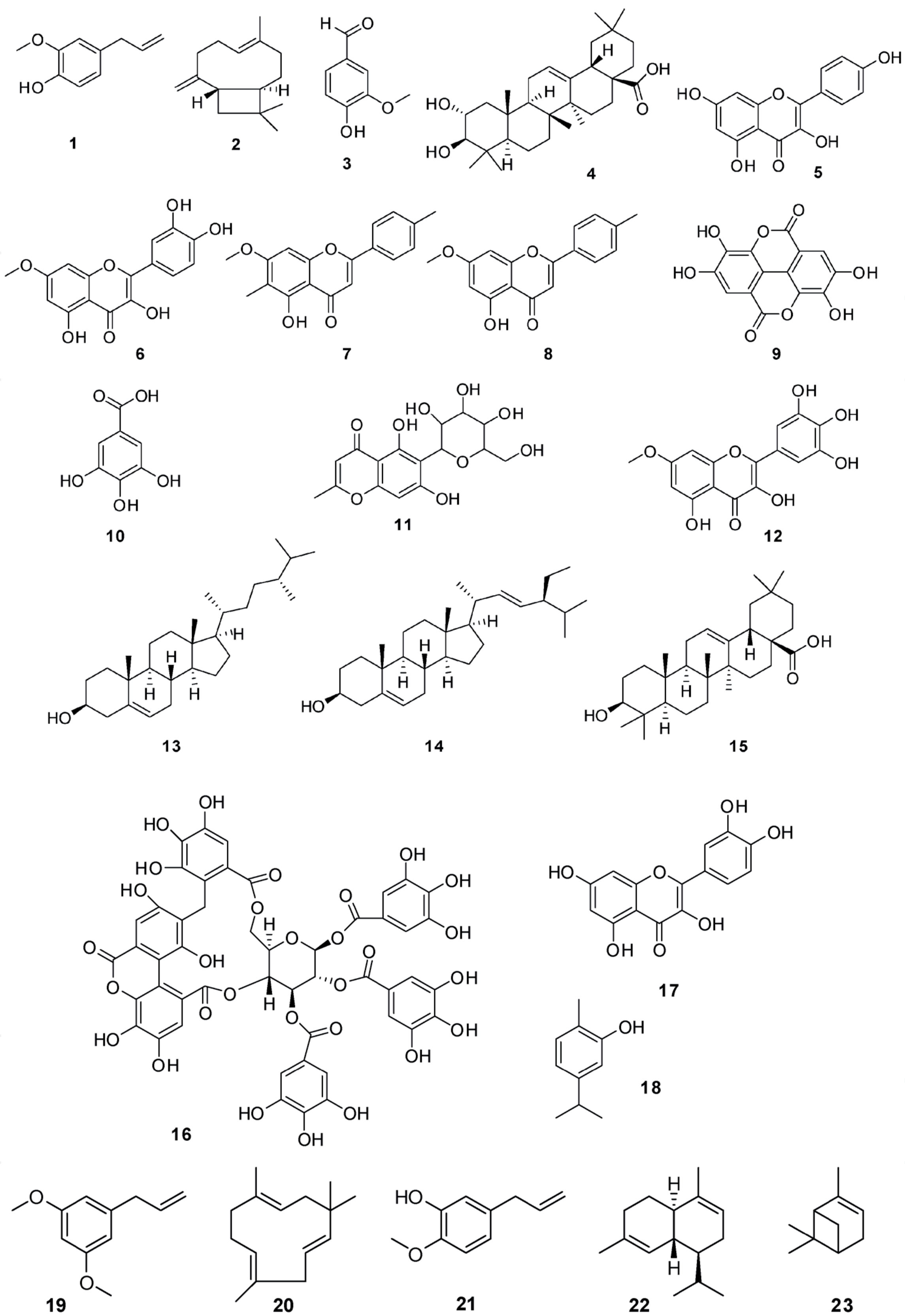

Figure 2.
Common constituents: (1) eugenol, (2) β-Caryophyllene, (3) vanillin, (4) Crategolic acid (5) Kaempferol, (6) Rhamnetin, (7) Eugenitin, (8) Eugenin, (9) Ellagic acid, (10) Gallic acid, (11) Biflorin, (12) Myricetin, (13) Campesterol, (14) Stigmasterol, (15) Oleanolic acid, (16) Bicornin, (17) quercetin (18) Carvacrol, (19) eugenol acetate, (20) α-Caryophyllene or α-humulene, (21) Chavibetol, (22) Cadinene (23) Pinene, (24).

preserved at low temperature because these bacteria multiply at low temperature and contaminate the food [35]. Singh, *et al.* (2003) [36] reported that clove oil was highly effective against *L. monocytogenes* in peptone water and reduced the bacterial population. The essential oil of Cloves (5%) reduced *L. monocytogenes*

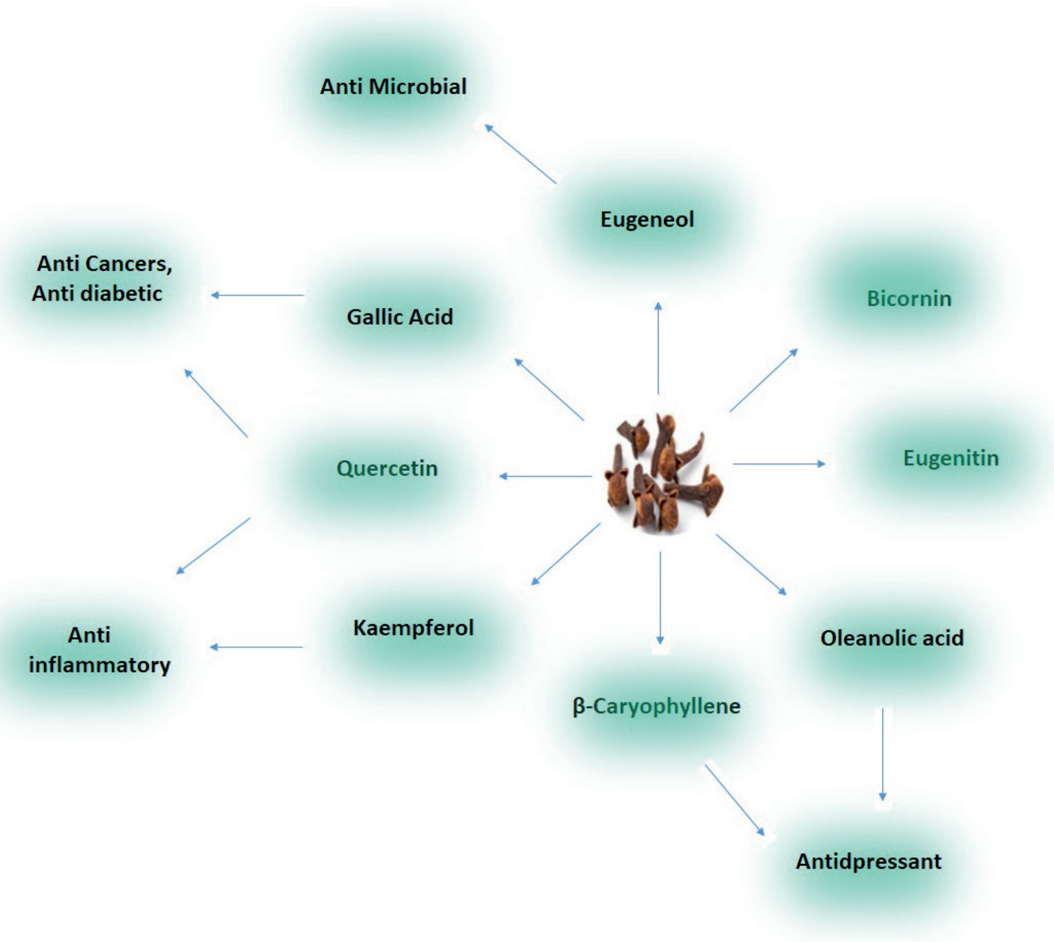

Figure 3.
Biological uses of compounds extracted from S. aromaticum.

cells to an undetectable level in ground chicken meat within one day of exposure, therefore, it can be used to control *L. monocytogenes* in ground chicken meat [37].

1.5 Antioxidant activity

In the past, oxidation mechanisms and free radical mechanism have been of great interest in living systems [38]. Oxygen uptake is essential to cell metabolism which results in the production of reactive oxygen species (ROS). The reaction of ROS with lipid molecules produces peroxyl radicals which further interact with nucleic acids and proteins results in alterations and, therefore, functional modifications [39]. ROS, include free radicals like superoxide anion radicals O_2^-, singlet oxygen, non-free-radical hydrogen peroxide and hydroxyl radicals are different forms of reactive oxygen species [40–43]. ROS are produced continuously during normal physiologic process and can easily lead to the peroxidation of lipids, which results in the accumulation of lipid peroxides. ROS is responsible for destroying crucial biomolecules like nucleic acids, proteins, lipids, as well as carbohydrates. They are also responsible for DNA damage that initiate the mutation [43, 44]. These suggest that, if the ROS are not adequately scavenged, they cause more than 100 of diseases like Alzheimer's disease, diabetes mellitus, hypertension [45, 46], prostate and colon cancers, coronary heart disease, atherosclerosis, cancer [47], cellular injury and aging process [48, 49], Therefore, to avoid the harmful effect of the ROS, can be blocked by antioxidant substances which scavenge the free radicals and detoxify the organism [50]. Antioxidants are those compounds that can protect the human body from free radicals and ROS effects and retard the progress of many chronic diseases by inhibiting the oxidation of lipid or other molecules by inhibiting the initiation or propagation of oxidizing chain reactions which suggest that Gallic acid, eugenol and eugenyl acetate have been used as an major antioxidants [51–55]. The antioxidant activity of eugenol and eugenyl acetate was found to be comparable to that of the natural antioxidant, vitamin E (α-tocopherol). Eugenol and *iso*-eugenol also found to be antioxidant and inhibit the peroxidation of lecithin induced by the Fe^{2+}-H_2O_2 system [56].

Gülçin, *et al.* [57] compare the scavenging of the DPPH radical of clove oil with some artificial antioxidant agents like α-tocopherol, BHT, Trolox, and butylated hydroxyanisole, and illustrated that the clove oil antioxidant activity declined as follows: Clove oil > BHT > α-tocopherol > butylated hydroxyanisole > Trolox. Numerous *in vitro* protocol including DPPH, oxygen radical absorbance capacity, ferric reducing antioxidant power, 2-deoxiguanosine, 2,20-azino-bis-(3-ethylbenzo-thiazoline-6-sulphonic acid) (ABTS), and xanthine oxidase have been employed to examine the antioxidant activity of aqueous *S. aromaticum* extract. After this studies, they illustrated that the potential antioxidant property of aqueous *S. aromaticum* extract may be due to the strong hydrogen donating ability, scavenging of hydrogen peroxide, free radicals and superoxide and metal chelating ability [58]. Therefore, the high antioxidant activity shown by clove oil is due the presence of phenolic compounds eugenol, thymol and eugenol acetate [59–61].

1.6 Antifungal activity

Several reports have been published which exhibit the antifungal activity of Clove oil which is further due to the presence of phenolic compound eugenol and carvacrol [62]. Pinto, *et al.* in 2009 [63] reported that Clove oil reduces the amount of specific fungal cell membrane ergosterol which cure the spread of fungal infection. Eugenol also inhibit the growth of filamentous fungi, yeast as human pathogenic fungi and fungal species born from food [64–66]. Kumar *et al.* in 2012 [67] reported that the phenolic compound carvacrol possess maximum antifungal activity against the *Candida fungal* species like *Candida albicans Candida tropicalis* and *Candida guilliermondii*. They also exhibited some antifungal activity contaminate bakery products by fungus such as *Eurotium spp., Aspergillus spp. and Penicillium spp*. These findings strengthen the possibility of using plant essential oils as an alternative to chemicals, to preserve bakery products [68]. Viuda-Martos, *et al.* [69] also reported the antifungal activity of Clove oil against food spoilage fungi *Aspergillus flavus* and *Aspergillus niger* by using agar dilution method and it was found that it exhibit stronger inhibition activity against *Aspergillus niger* than *Aspergillus flavus*. Bansod & Rai, in 2008 [70] further studied the comparative antifungal activity of different essential oils including Clove oil against *Aspergillus fumigates* and *Aspergillus niger* by using three different methods, disc diffusion method, broth dilution method and agar dilution method. Their studied further support the strong antifungal activity of Clove oil among all other oil. Estrada-Cano, *et al.*, 2017 [71] report the strong antifungal inhibitory action of encapsulated Clove oil against *Fusarium oxysporum* by oxford cup method. Based on the experimental observation they conclude that naked Clove oil had greatest inhibitory action against *Fusarium oxysporum* in beginning. But, after 8 hours the efficiency of microcapsulated Clove oil was maximum.

1.7 Anticancer activity

Cancer is the major public health problem in the worldwide and the number of patient increases continuously [72]. It is the second largest leading cause of death. When cancer is diagnosed at an advanced stage, chemotherapy is the most effective option to improve the patient's life to prolong time survival [73]. Recent literature survey revealed that some natural products have significant role as an antitumor agent. It is found that almost 30–40% drugs used globally for the treatment of cancer are derived from plant sources [74]. The dried buds of Cloves contain a wide range of bioactive compounds, which include eugenol, β-caryophyllene, humulene, chavicol, methyl salicylate, α-ylangene, and eugenone; the flavonoids eugenin, rhamnetin, kaempferol, and eugenitin; triterpenoids like oleanolic acid, stigmasterol, and campesterol; and several sesquiterpenes were screened as an anticancer agent. Haizhou Liu, *et al.* [75] reported that extract of Cloves displayed potent cytotoxic activity against several human cancer cell lines. They were performed *in vivo* antitumor activity of Clove extract by a number of experiments on variety of cancerous cell like human cancer cells, including ovarian cancer cells (SKOV-3), cervical epithelial cells (HeLa), liver cancer cells (BEL-7402), colon cancer cells (HT-29), breast cancer cells (MCF-7), pancreatic cells (PANC-1), normal colon epithelial cells (CCD 841 CoN), and normal lung fibroblasts (IMR-90) in order to identify the bioactive compounds. They were reported that the inhibition power of dried Clove powder in human colon cancer HT-29 cells by using the MTT assay was approximately 2.2 mg/mL. The antiproliferative effects was enhance by upto an approximate 10-fold by the use of the ethanol extract of Clove powder against a panel of human cancer cell lines, including breast (MCF-7), ovarian (SKOV-3), cervical (HeLa), liver (BEL-7402), pancreatic (PANC-1), and colon (HT-29) cells. After identification of inhibition activity, they were extract the bioactive compound from ethyl acetate extract of Cloves and found that oleanolic acid was the one of the bioactive component which has *in vitro* antiproliferative and *in vivo* antitumor activity. Kumar, *et al.* (2014) [76] reported the anticancer bioactive component of various concentrations of water, ethanol extract and essential oil of Clove *in vitro* through MTT and brine shrimp lethality test (BSLT) assay against MCF-7 human breast cancer cells. In both MTT and BSLT essential Clove oil showed excellent cytotoxic effect. In another study Lesgards, *et al.* (2014) [77] reported that Clove essential oil contains phenylpropanoids and terpenoids shows antitumor activity on both cell line and tumors in animals. Dwivedi, *et al.* (2011) [78] performed the comparative study of anticancer potential of Clove oil, its ethanol and water extract towards prostate cancer DU-145, cervical cancer HeLa, esophageal cancer TE-13, MDA-MB-231 (ER-ve) and breast cancer MCF-7 (ER + ve) along with normal human peripheral blood lymphocytes for antiproliferation by using MTT assay. Maximum cytotoxic activity and maximum cell deaths were observed in TF-13 cells within 24 hours by using essential Clove oil up to 300 μl/mL, whereas minimal cell death in DU-145 cells but with same dose no cytotoxicity was found in human peripheral blood mononuclear cells.

1.8 Anti-inflammatory activity

Cloves are well known for their anti-inflammatory effects. Traditional use of clove oil as a lotion or drinking of cloves in tea with daily routine may help to reduce inflammation caused by Arthritis. Past studies [79] have shown eating them on the daily could lead to major health benefits. Susan, *et al.* have concluded that DNA strand breaks and inflammatory biomarkers are a good functional measure of a food's bioavailability. Han, *et al.* [80] has recently provides important evidence of Clove essential Oil (CEO)-induced anti-inflammatory and tissue remodeling activity in human dermal fibroblasts. CEO at 0.011% concentration exhibit robust antiproliferative effects on human dermal fibroblasts. It significantly inhibited the increased production of several proinflammatory biomarkers such as vascular cell adhesion molecule-1 (VCAM-1), interferon-inducible T-cell α-chemoattractant

(I-TAC), interferon γ-induced protein 10 (IP-10), and monokine induced by γ interferon (MIG). CEO also significantly inhibited tissue remodeling protein molecules, namely, collagen-I, collagen-III, macrophage colony-stimulating factor (M-CSF), and tissue inhibitor of metalloproteinase-2 (TIMP-2). Furthermore, it significantly modulated global gene expression and altered signaling pathways critical for inflammation, tissue remodeling, and cancer signaling processes. CEO significantly inhibited VCAM-1 and collagen-III at both protein and gene expression levels. This study also supports the anticancer properties of CEO and its major active component eugenol. Barboza *et al.* [81] have reported that the eugenol a constituent of Clove exerts a beneficial action on oxidative stress through the inhibition of enzymes and oxidative processes, which is related to the anti-inflammatory drug profile of this compound. Sugihartini*et al.* [82] have also reported the activity of eugenol an essential oil component of Clove in absorption base ointment can be increased with the addition of enhancer. Its activity was better than natrium diclofenac in positive control. However, the formula containing propylene glycol needs to be evaluated for its anti-inflammatory activity for a longer duration to ensure its effectivity. Banerjee *et al.* [83] have reported that Clove oil emulsion can substitute chemical based topical products for anti-inflammatory and wound healing applications. Nikoui et al. [84] have also reported that clove oil administration has anti-inflammatory and antipyretic properties in dogs after surgery. Leem et al. [85] have reported that, among the volatile distillate extracts of 8 herbal medicines, the distillate extract of cloves exhibited the strongest antioxidant activity (IC_{50} = 8.85 μg/mL) and COX-2 inhibitory activity (inhibition rate was 58.15% at 10 μg/mL concentration), whereas 15-LOX inhibitory activity (inhibition rate was 86.15% at 25 μg/mL concentration) was the second highest after Angelica. They also measured an antioxidant and anti-inflammatory activities of eugenol and its derivatives (methyl eugenol and acetyl eugenol), eugenol (IC_{50} = 5.99 μg/mL), which exhibited the highest antioxidant activity, whereas methyl eugenol and acetyl eugenol exhibited a little activity. In the case of COX-2, eugenol (85.35%) at a concentration of 20 μg/mL showed the strongest inhibitory activity, whereas in 15-LOX, methyl eugenol (83.29%) at a concentration of 20 μg/mL showed the strongest inhibitory activity, whereas in 15-LOX, methyl eugenol (83.29%) at a concentration of 20 μg/mL showed the highest inhibitory activity.

1.9 Antidiabetic activity

Kroda *et al.* [86] have reported that Clove (*Syzygium aromaticum* flower buds) EtOH extract significantly suppressed an increase in blood glucose level in type 2 diabetic KK-A(y) mice. The results indicate that clove has potential as a functional food ingredient for the prevention of type 2 diabetes and that 2–4 mainly contribute to its hypoglycemic effects via PPAR-γ activation. *In-vitro* evaluation exhibited the extract had human peroxisome proliferator-activated receptor (PPAR)-γ ligand-binding activity in a GAL4-PPAR-γ chimera assay. They isolated 8 compounds, of which dehydrodieugenol and dehydrodieugenol B had potent PPAR-γ ligand-binding activities and also showed to stimulate 3 T3-L1 preadipocyte differentiation through PPAR-γ activation, whereas major constituent oleanolic acid in the EtOH extract, had moderate activity. Topal [87] reported that Isoeugenol (2-methoxy-4-(prop-1-en-1-yl)phenol), a constituent of clove oil exhibited excellent inhibitory effects against some metabolic enzymes viz. acetylcholinesterase (AChE) enzymes, α-glycosidase, and α-amylase. Isoeugenol has the IC_{50} values of 411.5, 19.25 and 77.00 nM for α-amylase, α-glycosidase and AChE, respectively. The K_i values of isoeugenol were found as 21 ± 9 and 16 ± 3 nM against α-glycosidase and AChE, respectively, whereas, tacrine as standard AChE inhibitor exhibited IC_{50} value of 20.38 nM. α-Glycosidase inhibitors, commonly referred to as starch blockers, are anti-diabetic drugs that help reduce edible blood glucose levels. Chaudhry *et al.* [88] reported that Clove extract has glucose lowering effect in STZ induced diabetic rats and this effect is dose related and the dose of 750 mg/kg body weight has produced maximum effect. Abdulrazak et al. [89] have evaluated the effects of clove and fermented ginger supplements on blood glucose, serum insulin, insulin receptor and Leptin levels of high fat diet-induced type-2 diabetes mellitus in rabbits. They found a significantly ($P < 0.05$) decrease in blood glucose levels was recorded in the supplements treated groups compared to diabetic control group. Clove supplement has been most effective and sustaining in antihyperglycemic activity, also appears with a significant decreasing effect on leptin levels compared to diabetic control group. A significant increase in insulin levels was also detected in the fermented ginger treated group along with higher levels of Leptin compared as compared to control group. Thus overall, the study reveals that clove and fermented ginger supplementation possesses anti-diabetic properties and may help in the control of hyperleptinaemia in type 2 diabetes.

1.10 Herbicidal activity

Clove oil also exhibit herbicidal activity against the many herbicides. Tworkoski (2002) [90] investigated the herbicidal of different essential oils including Clove and Cinnamon oil on detached leaves of dandelion. Clove and Cinnamon essential oil were applied using dandelion leaf disk assay and whole plant assay with Johnson grass, common lambsquarters and common ragweed in green house. The observed that shoot death occurred from one hour to one day after the application of oil. Bainard, *et al.* (2006) [91] investigated the herbicidal activity of Clove oil and its primary constituent eugenol on *Amaranthus retroflexus* (redroot pigweed), *Chenopodium album* (common lambsquarters) and effect on leaf cell membrane integrity and seedling growth. They observed that Clove oil and its major constituent eugenol caused reduction in cell membrane integrity and inhibition of seedling growth. Evans, *et al.* (2009) [92] performed their studies on herbicidal effect of Clove oil and vinegar on *Abutilon theopharst* (velvet leaf) and *Amaranthus retroflexus* (redroot pigweed). In their studies they were found that redroot pigweed was easier to control with both products than velvetleaf. Park, *et al.* (2011) [93] further investigate the herbicidal action of Clove oil on the cucumber seedlings in light and dark conditions. Clove oil treatment increased superoxide dismutase (SOD) activity and decreased catalase activity whereas SOD and catalase activity decreased in the paraquat treatment. They reported that the Clove oil exhibit herbicidal action through a mechanism different from that of parquet.

Besides this they also exhibit insecticidal activity, anesthetic activity and several literatures are available on that. Rom these studies we observed that the essential oil present in Clove are beneficial and are in use for treatment of variety of disease.

2. Conclusion

Overall, *Syzygium aromaticum*, is an essential herb which contains many essential oils, terpenoids, flavonoids, polyphenols, eugenol and many other active pharmacaphores. These leading pharmacophore made *S. aromaticum* a special plant to treat many disease like cancer, Alzhimer and many body infections and dis-regulations. Traditional use of this is widely known whereas, it is scientifically proved as well. It can be used as antimicrobial, antibacterial, antifungal, antioxidant, anticancerous, antiherbicidal, antidiabetic, anti-inflammatory, antidepressant, antiulcer, antinoceptive, and antiprotozoal etc.

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